STUDIES OF EPOXY POWDER COATED GALVANIZED STEEL SUBSTRATE VIA ELECTROSTATIC POWDER COATING SYSTEM

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Thesis submitted in partial fulfilment
of the requirement for the Master
in Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
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FEBRUARY 2012

ACKNOWLEDGEMENT

In the name of Allah the most gracious the most merciful, I would like to appreciate to my colleague and friends who helped to make this research project successful.

First of all, I would like to express the gratitude to my supervisor, Dr. Rosli Bin Ahmad for his openness to help me and give guidance in completing my research work. He is a person who has a vast knowledge and experience. I had a tremendous learning experience and I truly honoured and privileged. His cooperation and advice is highly appreciated.

Special gratitude goes to Liebherr Appliances Kluang Sdn. Bhd. staff for the time spent with me by enriching ideas and as well as in the form of assistance, especially while conducting experiment.

My deepest appreciation, thanks and love goes to my parents, Ajer Bin Abdul Rahman and Siti Binti Mansur and also to my wife Hadijah Binti Ahmad who always been very supportive and ever willing to share all my joy and pain.

To those who indirectly contributed in this research, your kindness means a lot to me. To all my fellow friends and my families who understand my responsibilities and needed, thanks again.

ABSTRACT

This research deals with epoxy powder coating on the electrolytic galvanized steel sheet via electrostatic powder coating system. Normally, the film thickness and powder coverage of the coated powder is not optimum. It leads to non- protection of the parts from rusty and corrosion besides having many defects such as orange peel, rough surface, poor adhesion and inconsistencies of colour tone. In order to produce good coating quality, the processing parameters must be optimized. In this research, there have three variable parameters need to investigate. The variable parameters are total air volume, powder output and spraying distances. These parameters were screening to determine the significant effects to the coating quality. The screening result shows the spraying distance does not have significant effects and it was discarded. The experiments were carrying out to determine the optimum combination of powder output and total air volume. It is purposely to produce sample with good coating quality besides improved the first pass transfer efficiency (FPTE). All samples were tested using same processes that are pre-treatment, dry-off, powder spraying and curing. The method used to investigate the coating characteristic are thickness measurement, Buchholz indentation test, cross cut test, colour visual checking, particle cross-linking struture and surface profile analysis. The instruments used to evaluate the samples are coating thickness gauge, Buchholz indentor, multi blade cutting tools, spectrophotometer, scanning electron microscope (SEM) and surface profiler. The experimental result shows the combination of 4.0 m^3/h of total air volume and 150 g/min of powder output produce good coated sample with optimum thickness and colour tone. It also has good particle crosslinking structure and surface profiler. The coating indentation resistant and adhesion for this sampe is able to protect the galvanized steel from corrosion and rusty.

ABSTRAK

Kajian ini membincangkan berkenaan dengan lapisan serbuk epoxy pada kepingan besi bergalvani menggunakan system lapisan serbuk elektrostatik. Kebiasaannya, ketebalan lapisan dan liputan lapisan serbuk adalah tidak optimum. Ia akan membawa kepada tiada perlindungan bahan daripada karat dan hakisan selain mempunyai banyak kecacatan seperti permukaan kasar seperti kulit oren, kurang kelekatan dan ketidakseragaman warna. Dalam usaha untuk menghasilkan kualiti lapisan yang baik, parameter proses mestilah dioptimumkan. Dalam kajian ini, terdapat tiga parameter pemboleh ubah yang perlu dikaji. Parameter tersebut ialah jumlah isipadu udara, pengeluaran serbuk dan jarak penyemburan. Parameter ini akan ditapis untuk menentukan kesan-kesan yang ketara pada kualiti lapisan. Keputusan tapisan mendapati jarak semburan tidak mempunyai kesan yang ketara dan ianya telah diabaikan. Eksperimen telah dijalankan untuk menetukan kombinasi yang optimum untuk pengeluaran serbuk dan jumlah isipadu udara. Ianya bertujuan untuk menghasilkan sampel yang mempunyai kualiti lapisan yang baik sekaligus memperbaiki kadar kecekapan penghantaran yang pertama. Kesemua sampel telah diuji menggunakan proses yang sama iaitu pra-rawatan, pengeringan, penyemburan serbuk dan pembakaran. Kaedah yang digunakan untuk mengkaji sifat-sifat lapisan ialah pengukuran ketebalan, ujian lekukan Buchholz, ujian keratan silang, pemeriksaan warna, analisis struktur zarah dan ciri-ciri permukaan. Peralatan yang digunakan untuk menilai sampel ialah tolok ketebalan lapisan, pelekuk Buchholz,alat pemotong pelbagai bilah, spectrophotometer, imbasan mikroskop elektron dan pembentuk permukaan. Hasil eksperimen menunjukkan kombinasi 4.0 m^3/h jumlah isipadu udara dan 150 g/min pengeluaran serbuk menghasilkan sample lapisan yang baik dengan ketebalan lapisan dan warna yang optimum. Ianya juga mempunyai struktur zarah-zarah dan profil permukaan yang baik. Rintangan lekukan dan kelekatan juga mampu untuk melindungi besi bergalvani daripada karat dan hakisan.

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1	Cutting edge
a	Width across all six cutting edges
l	Indentation length (mm)
h	Indentation depth (µm)
αB	Indentation resistant
OEMS	Original equipment manufacturers
EG	Electrolytic Galvanized
DSC	Differential Scanning Calorimetry
DMTA	Dynamic Mechanical Thermal Analysis
FPTE	First Pass Transfer Efficiency
ISO	International Organization for Standardization
OFAT	One factor at a time
CIE	Commission International d'Eclairage
SEM	Scanning electron microscope
SCI	Specular component included
SCE	Specular component excluded
BSE	Back-scattered electrons

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CHAPTER 1

INTRODUCTION

1.1. History of powder coating technology

The history of powder coating technology started around late 1940s when thermoplastic powder applied as coatings to metal and other substrates by flame spraying. In this process, a plastic powder fed through a flame spraying apparatus where the plastic particles melted and propelled by the hot gases to the substrate. A patent issued in Great Britain to Schori Metallising Process Ltd. in 1950 described a process for forming a coating in which thermoplastics powder applied to a heated substrate by dipping or rolling the heated parts in the plastic powder. This process is difficult to practice and never achieved commercial success.

A major breakthrough in powder coating occurred in the mid-1950s, when Erwin Gemmer conceived the fluidized-bed coating process, in which a heated object is dipped into a fluidized bed of powder. Gemmer involved in developing flame spraying processes and materials in the laboratories of Knapsack-Griesheim, a manufacturer of specialty gases and searching for a more efficient method than flame spraying for coating objects with powder. The first patent applications filed in Germany in May 1953. The basic patent issued and the Polymer Corporation acquired rights to the Knapsack Griesheim patents. The Polymer Corporation mounted an aggressive effort to develop, license and sell fluidized-bed coating technology in North America. However, acceptance of this coating process was rather slow. In 1960, the annual sales of coating powders in United States below 450 thousand because of a lack of expertise in the methodology. In addition, the available powder coating materials is expensive, efficient production techniques had not been worked out and volume of production is low.

Today, powder coating is widely accepted with thousands of installations in the factories of original equipment manufacturers (OEMS) and custom coating job. It is the preferred method for coating many familiar items such as lawn and garden equipment, metal furniture, electrical cabinets, lighting, shelving and store fixtures and automotive components.

1.2. Electrostatic powder coating technique

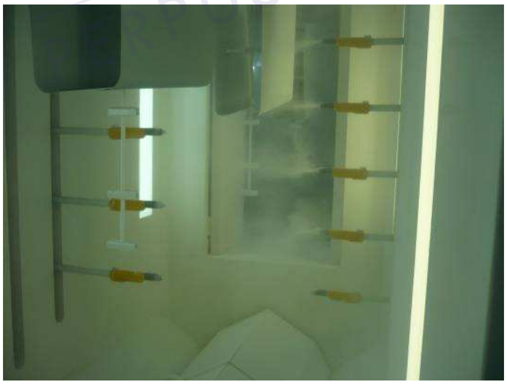
Electrostatic powder coating technique is one of the most environmentally friendly and economical technologies in surface treatment. Since early 60's, powder coating paints have been available on the market and the problem free production and processing made powder coating a well established and commonly recognized technique. Powder coating is a dry coating. Instead of being dissolved or suspended in a liquid medium such as solvent or water, powder is applied in a granular form. This material is finer than ground pepper but coarser than flour. It is applied directly to the surface to be coated. The powder created by blending the various components such as binders, resins, pigments, fillers and additives and then processing through an extruder into a continuous mass. This homogenous mass is cooled and broken into small chips which are then ground into the powder. Each powder particle contains within it the necessary components for reforming into the finished coating. After the powder applied to the part typically using an electrostatic spray process, the part passes through an oven and melting into a smooth film on the surface of the part. Figure 1.1 and 1.2 shows the electrostatic powder coating system used for this research.

Powder centre

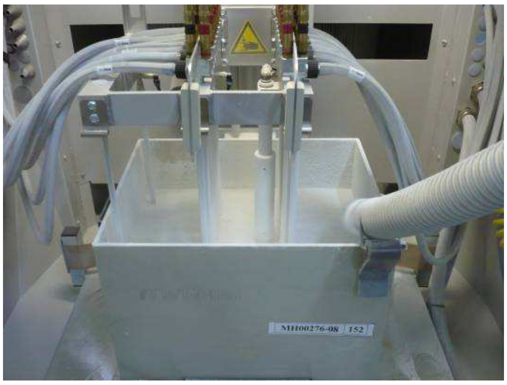
Display panel

Fresh powder system

Control panel



Spray booth



Fluidized bed

Figure 1.1: ITW Gema electrostatic powder coating

Degreasing and rinsing tank

Pre-treatment system

Dry off oven

Baking oven

H_2O Water treatment

Pre-treatment control panel

Figure 1.2: Combat pre-treatment, oven and conveyor system

Although powder coating is an economical technology in surface treatment, it needs further research to improve some critical issues in powder coating system. The main issue for powder coating is normally the film thickness after cured is not optimum. Insufficient of film thickness will cause the parts surface have poor powder coverage. It leads to non protection of the parts from rusty and corrosion. If the film thickness is very high, the coating layer is easy to peel off and having poor adhesion. This research was targeted to determine the optimum thickness of the coating film. The optimum thickness will have good surface protection to the corrosion and rusty. The coated films also have a good adhesion and indentation resistant. The methods used to evaluate the coating characteristic are thickness measurement, cross-cut test, Buchholz indentation test, particle structure analysis and surface profile. These methods will be explained in detail in chapter 3.

There are some parameters considered to get the optimum coating thickness. The parameters are powder output, total air volume and spraying distances. All of these parameters were affected to the powder mass flow rate. The powder mass flow rate is the mass of substance which passes through a given surface per unit time. The powder mass flow rate in electrostatic powder coating is depending on the powder output and total air volume. The amount of powder moving out from the nozzle must be supported by optimum total air volume to ensure the powder reach the parts. This research were carried out 15 experiments to investigate the significant effect of the processing parameters and 25 experiments to determine the optimum combination of powder output and total air volume.

The other challenge in powder coating is to get maximum first pass transfer efficiency during powder spraying. In powder coating, transfer efficiency is the ratio of the quantity of powder deposited on the part to the quantity of powder directed at the part. Transfer efficiency is given as a percentage, with 100% being most desirable. It is always desirable to improve first-pass transfer efficiency, maximize the efficiency of the initial coating application to minimize costs. Collection of any overspray which can be conditioned for reuse will affect the transfer efficiencies. Overall transfer efficiency will be higher if using the reclaim system. But, more cost benefits can be realized by achieving high first-pass transfer efficiency. The most efficient application occurs when

100% of the applied coating deposited uniformly on the part, leaving no excess coating for collection, disposal or reuse. Use of a reclaim system can push overall efficiency to 90% or greater. Maximizing first-pass transfer efficiency will reduce the amount of powder over sprayed and subsequently the amount of reclaim generated. High first pass transfer efficiency will generate smaller quantities of reclaim. The reclaim powder can be reuse. However, it can not be 100% reuse because the reclaim powder may have some dust or additives. It must be mixing with fresh powder. Based on the previous paper, the powder output and total air volume are strongly influences the first pass transfer efficiency of the powder to the parts. This research determined the optimum level of air to support the powder to the parts to get the maximum transfer efficiency. It shows clearly that increasing in transfer efficiency is one improvement that can lower costs, improve productivity and increase quality.

During powder spraying, there have three forces acting to ensure the powder reach the parts. The forces are aerodynamic, gravity and electric force. The aerodynamic force must be overcome the gravity force to ensure the powder can reach to the parts. Aerodynamic force is the resultant force exerted on a body by the air in which the body is immersed and is due to the relative motion between the body and the fluid. An aerodynamic force arises from the force due to the pressure on the surface of the body. The powder must be supporting by sufficient air volume to ensure the aerodynamic force overcome the gravity force during powder spraying. If the air volume is not optimum, the gravity force will overcome the aerodynamic force. It will cause the powder falling down before reach the parts as well as reducing the first pass transfer efficiency. This paper will carry out experimental investigation to determine the optimum combination of powder output and the total air volume to ensure the powder can reach the parts with the maximum transfer efficiency.

1.3. Advantages

Over the past decade, powder coating has been increasingly accepted as the preferred finishing process for the future. The advantages for electrostatic powder coating are shows in table 1.1 below.

Table 1.1: Advantages of the electrostatic powder coating system

Advantages	**Description**
Economy	I. Material utilization is much higher with powder, making material costs much lower. 92% to 98% of powder may be applied to the parts versus an average of 60% with an electrostatic liquid system and the other 40% is waste and must be disposed off. II. Since most of the material is used on the part, there is very little waste. III. The powder is not considered hazardous waste, so the cost of disposal is minimal compared to the high cost of toxic waste disposal. IV. Air loss from the curing oven is minimized as there is only a very small amount of volatile substance that must be exhausted. The cost of maintaining oven temperatures is therefore minimized. V. Powder is simpler to spray, so less skilled labour is needed, training is easily done and fewer errors are made in coating. VI. It saves scrap, labour and ultimately, operating costs.
Excellence	I. The cured powder finish is less susceptible to damage than a liquid finish. There is less need for repair work on the finished item and packaging is less elaborate, saving time and cost on rework and packaging. II. Epoxy, acrylic and hybrid powders provide excellent adhesion and hardness for improved resistance to chipping, abrasion, corrosion and chemicals and it is flexible enough to be formed without cracking. III. Polyester powders provide additional advantages in ultraviolet and weathering resistance.

Table 1.1: Advantages of the electrostatic powder coating system (cont)

Advantages	Description
Ecology	Powder is the overwhelming preference of the EPA, eliminating: I. Solvent fumes and VOCs from spray booth and oven exhausts that pollute the air. II. Potentially toxic sludge and water that can contaminate the earth and must be disposed of as hazardous waste.

The limitation is electrostatic powder coating not as easy to apply smooth thin films. As the film thickness is reduced, the film becomes more orange peeled in texture due to the particle size of the powder. For optimum material handling and ease of application, most powder coatings have a particle size in the range of 30 to 60 µm. For such powder coatings, film build-ups of greater than 60 µm required to obtain an acceptably smooth film. The acceptable surface texture depends on the end product.

1.4. Problem statement

“The significant effect of the processing parameters need to be determine because it will affect the coating quality”

“The combinations of the powder output and total air volume must be optimizing to have good coating characteristic”

“The thickness must be optimum to have good particle cross-linking structure and surface profile to protect the surface from any defects such as corrosion and rusty”

1.5. Objectives

The objectives for this research are listed below:

1. To investigate the significant effects of the powder output, total air volume and spraying distances to the coating characteristic
2. To determine the optimum combination of powder output and total air volume to have optimum thickness besides having maximum first pass transfer efficiency of the powder to the parts and good coating quality

1.6. Scopes

The scopes for this research are listed below:

1. The samples substrate used for this research is electrolytic galvanized (EG) sheet metal
2. The type of powder used for this research is thermosetting resin epoxy powder
3. All experiments used automated appliances for the electrostatic powder coating processes

1.7. Limitations

The limitations for this research are listed below:

1. The metallic colour can not be studying because it has special effects for the powder contact, charging characteristic and surface appearances
2. The other types of sheet metal exclude electrolytic galvanized (E.G) cannot be studying because it has different surface contact characteristic

CHAPTER 2

LITERATURE REVIEW

2.1 Coating powders

There have two types of powders that are commonly used for electrostatic powder coating. The powders are thermoplastic and thermosetting resin.

Richart (2000) conducted experiments to investigate melt viscosity of thermosetting and thermoplastic powder. Thermoplastic resins have a melt viscosity higher than thermosetting resins at normal baking temperatures. Therefore, difficult to thermoplastic resins sufficiently to obtain complete hiding in thin films. Thermoplastic resins are much more difficult to grind to a fine particle size than thermosetting resins. Grinding must be carried out under cryogenic conditions. In order to produce fine powders, a cryogenic system was established using liquid nitrogen where a jet-vortex mill used as a grinding mill.

Waelde (2005) investigated the particle size distribution and application for thermosetting and thermoplastic powder. Thermosetting powder was used for electrostatic spraying because the system was designed to have a maximum particle size of about 75 µm. The thermoplastic powders are predominant in the fluidized-bed coating process where heavier coatings applied and a larger particle size can be tolerated. Fluidized-bed powders typically contain only about 10 to15% of particles below 44 µm whereas the high end of the particle-size distribution ranges up to about 200 µm. It is not possible to develop thin coated film.

Rusk et al. (2000) investigated the melting flow characteristic of the thermosetting and thermoplastic powder that can affect to the coating appearances. Rusk et al. found thermosetting resins are more versatile than thermoplastic resins. The resin agent system possesses a low melt viscosity allowing application of smoother films. Necessary level of pigment and fillers required to achieve thin film can be incorporated without affecting flow, gloss and texture. Manufacturing costs are lower because compounding was carried out at lower temperatures. The resins are friable and can be ground to a fine powder without using cryogenic techniques. Thermoplastic resin have poor melt flow characteristic compared with thermosetting powder. The way to improve the melt flow characteristics of a polymer is by lowering the molecular weight and blending with a compatible resin of lower molecular weight. However, it can result in poor physical properties or a soft film in the applied coating. Attempts to improve the melt flow by increasing the application temperature are limited by the heat stability of the polymer. If the application temperature is too high, the coating shows a significant colour change or evidence of heat degradation.

Litchneker (1999) studied the chemical reaction and cross-linking of the thermoplastic and thermosetting resin. Thermoplastic coatings do not chemically react upon temperature increase but it flow and melt on the substrate. Thermosetting coatings also melt upon temperature increase, but under go a simultaneous chemical reaction and polymerize through cross-linking into resistant film. Once this chemical reaction has occurred the powder coating cannot melt again. It have better chemical and impact resistant after cured compared with thermoplastic coating

Pekarik (2009) investigated the physical properties of the thermosetting and thermoplastic powder. The physical properties of a thermoplastic powder depend upon the type of resin and initial molecular weight. Thermosetting resin systems are low-molecular-weight solids that go through a melt fusion and chemical reaction to form higher-molecular-weight polymers. Thermosets are characterized as heat cured and will not remelt when heat is applied. It have better surface appearances and adhesion to steel compared with thermoplastic resin. Thermoplastic powders had some limitations including high fusion temperatures, poor adhesion to metal and high applied cost.

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